FIRE DEPARTMENT RESPONSE TIMES & RUN ORDERS

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OBJECTIVES

- Evaluate currently established service areas and run orders
- Identify areas of vulnerability or concern for further investigation
- Provide baseline data for future What If? scenarios like…
  - Addition or removal of a fire station
  - Relocation of an existing station
  - Bridge or road closures
  - New neighborhood response times
  - Loss or addition of apparatus

HOW CAN THIS BE ACCOMPLISHED?

- Network Analyst Software Extension (ESRI)
  - Provides Network-based Spatial Analysis
  - OD Cost Matrix (Origin-Destination)
  - Shortest Route (Distance or Time)
  - Service Area
- Network Data
- Destinations (E911 Address Points) & Highway Points
- Project Plan
  - How to Model Real World?
  - Project Parameters
    - Assumptions
    - Limitations

NETWORK DATA BASIC NEEDS

- Network Edge Data (i.e. Roadways)
  - Segment Lengths
  - Speed Limit
  - Cost (Travel Time)
  - One Way?
  - Hierarchy (Used Teleatlas ACC – Arterial Classification Code)

NETWORK DATA

- Cranston Streets Lacked Basic Network Data
- Routes Could Be Solved Using Streets Outside the City (No Data)
- Commercially Available Data Cost Prohibitive (2010/2011)
  - Annual Subscriptions
  - Couldn't Control Road Segment IDs – Problem for Developing Stop Sign/Traffic Signal Impedances

NETWORK DATA

- Develop Our Own?
- ESRI Provided 2005 TeleAtlas Data for RI – Starting Point
  - Speed Limits
  - One-Way
  - ACC Codes (Arterial Classification Codes)
- We Improved 2005 TeleAtlas Data in Cranston Only

NETWORK MODEL ELEMENTS

What things affect drive time that we can model?

- Driving Speed
- Roadway Conditions (Dry, Wet, Snow/Ice)
  - Factors into Stopping Distance
  - Increased Stopping Distance = Longer Drive Time
- Stop & Yield Signs
  - New GIS Inventory (2800 +/-)
- Traffic Lights
  - 77 Intersections
- Turns, Right and Left
  - Similar to Stop Sign
- One-Way Streets
- 2 Minute "Turn-Out" Time – Contributes to Overall Response Time

WEATHER IMPACT/STOPPING DISTANCES

Q: How much longer does it take to decelerate, stop and accelerate back to your original speed, as compared to not having to stop at all?

Response Time Analysis - Network Impedance Values **Scenario: Dry Roads, Average Conditions**

The purpose of these calculations is to determine how much longer it takes a vehicle to come to a complete stop and continue accelerating to its original speed, than it does if you drove through the same distance without stopping. These values will be used to model drive time delays for stop and yield signs, traffic lights, and right and left hand turns in our network analysis.

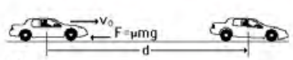
Assumptions

Coefficient of Friction - Dry Road Conditions, Average Conditions	** f =	0.56	Perception Time, P	1.25	seconds
Acceleration due to gravity, g (ft/sec^2)	g=	32.2	Reaction Time, R	1.25	seconds
Acceleration and Decelaration are constant while stopping and returning to desired speed.			Calculations based on level driving surface		
Time to Stop equals Time to Continue back to the same speed.			** Conservative value based on AASHTO Geometric Design of Highway and Streets		

Speed MPH S	Speed Ft/Sec V =S*1.466	(Stopping) Deceleration Distance Ft Dstop = [V^2]/(2*f*g)	Acceleration Distance Ft Daccel = [V^2]/(2*f*g)	Acceleration Ft/Sec^2 a =f*g	Deceleration Ft/Sec^2 d =f*g	Time to Stop Seconds Tstop =(V-0)/d	Time to Accelerate from a Stop to Desired Speed Seconds Taccel =(V-0)/a	Time to Drive at Constant Velocity over Accel + Stopping Distance Seconds T =(Dstop+Daccel)/V	Network Impedance for Network Analyst Seconds I =[(Tstop+Taccel)-T] + P + R	Network Impedance for Network Analyst Minutes I/60
15	21.99	13.7	13.7	17.7	17.71	1.24	1.24	1.24	3.74	0.06236
16	23.456	15.5	15.5	17.7	17.71	1.32	1.32	1.32	3.82	0.06374
17	24.922	17.5	17.5	17.7	17.71	1.41	1.41	1.41	3.91	0.06512
18	26.388	19.7	19.7	17.7	17.71	1.49	1.49	1.49	3.99	0.06650
19	27.854	21.9	21.9	17.7	17.71	1.57	1.57	1.57	4.07	0.06788
20	29.32	24.3	24.3	17.7	17.71	1.66	1.66	1.66	4.16	0.06926
21	30.786	26.8	26.8	17.7	17.71	1.74	1.74	1.74	4.24	0.07064
22	32.252	29.4	29.4	17.7	17.71	1.82	1.82	1.82	4.32	0.07202
23	33.718	32.1	32.1	17.7	17.71	1.90	1.90	1.90	4.40	0.07340
24	35.184	34.9	34.9	17.7	17.71	1.99	1.99	1.99	4.49	0.07478
25	36.65	37.9	37.9	17.7	17.71	2.07	2.07	2.07	**4.57**	0.07616
26	38.116	41.0	41.0	17.7	17.71	2.15	2.15	2.15	4.65	0.07754
27	39.582	44.2	44.2	17.7	17.71	2.24	2.24	2.24	4.74	0.07892
28	41.048	47.6	47.6	17.7	17.71	2.32	2.32	2.32	4.82	0.08030
29	42.514	51.0	51.0	17.7	17.71	2.40	2.40	2.40	4.90	0.08168
30	43.98	54.6	54.6	17.7	17.71	2.48	2.48	2.48	**4.98**	0.08306
31	45.446	58.3	58.3	17.7	17.71	2.57	2.57	2.57	5.07	0.08444
32	46.912	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	65	2.65	5.15	0.08581
33	48.378	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	73	2.73	5.23	0.08719
34	49.844	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	81	2.81	5.31	0.08857
35	51.31	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	90	2.90	5.40	0.08995
36	52.776	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	98	2.98	5.48	0.09133
37	54.242	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	06	3.06	5.56	0.09271
38	55.708	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	15	3.15	5.65	0.09409
39	57.174	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	23	3.23	5.73	0.09547
40	58.64	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	31	3.31	5.81	0.09685
41	60.106	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	39	3.39	5.89	0.09823

Stopping Distance For A Vehicle

Assuming proper operation of the brakes on the vehicle, the minimum stopping distance for a vehicle is determined by the effective coefficient of friction between the tires and the road, and the driver's reaction time in a braking situation. The friction force of the road must do enough work on the car to reduce its kinetic energy to zero. If the wheels of the car continue to turn while braking, then static friction is operating, while if the wheels are locked and sliding over the road surface, the braking force is a kinetic friction force only.



To reduce the kinetic energy to zero:

$$Work_{friction} = -\mu mgd = -\frac{1}{2}mv_0^2$$

so the stopping distance is

$$d = \frac{v_0^2}{2\mu g}$$

Note that this implies a stopping distance independent of vehicle mass, and in this case, driver reaction time. It also implies a quadrupling of stopping distance with a doubling of vehicle speed.

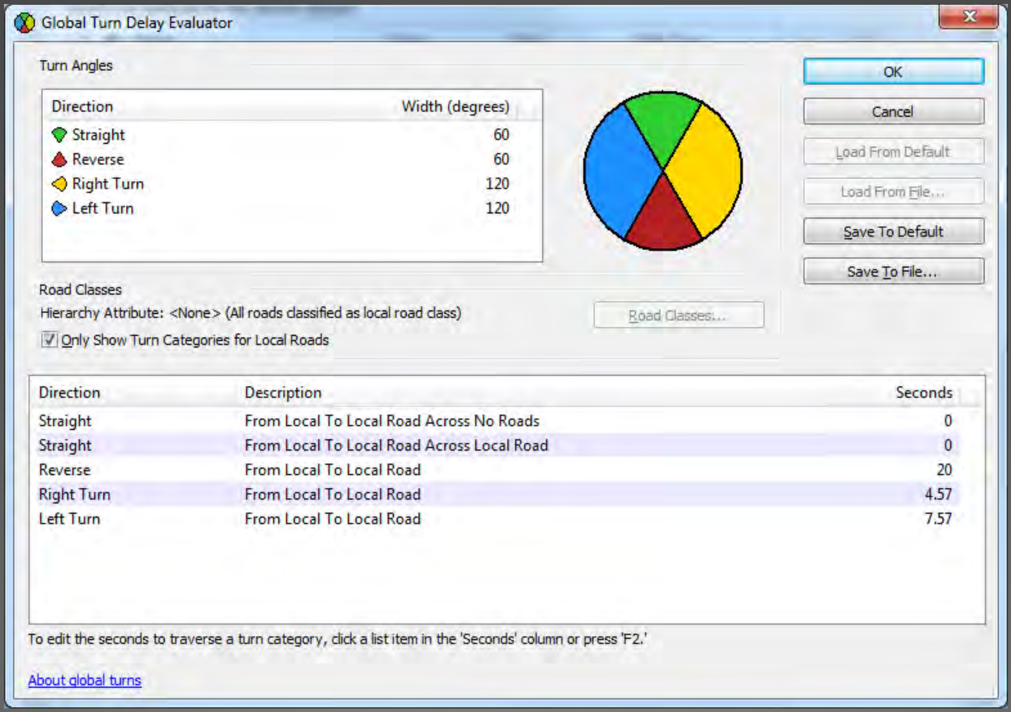
- Coefficient of Friction
  - Dry: 0.55
  - Wet: 0.3
  - Snow/Ice: 0.1
- Perception Time 1.25 sec
- Reaction Time 1.25 sec

Affects Network Costs of Stop Signs, Traffic Signals, Global Turns (Left/Right)

NETWORK TURN FEATURES

- A Turn models a movement from one edge element to another.
- Model the additional travel time imposed by having to navigate stop/yield signs or traffic light intersection.
- Stop/Yield/Traffic Lights
  - 2400 Turn Records Developed
- Can Specify Default Turn Cost using Global Turn Delay Evaluator
  - Imposed additional travel time for Right or Left Turn and Reverse
  - Can also use for Straight
  - Customize Values

GLOBAL TURN EVALUATOR



- Values derived from Stopping Distance Calculations
- Changed for Each Environmental Condition

PROJECT PARAMETERS

Q: How do we decide the magnitude of the impact of Model Elements?
A: Create a Range of Extreme Conditions.

Best Case

- No Traffic (3am)
  - Drive Speed Limit + 15 mph
- Dry Pavement
  - Baseline Stopping Distances/Time
- No Stop Signs
- Traffic Signals All Green
- No Delays to Make a Turn

Worst Case

- High Traffic Volume (8am/5pm)
  - Reduce Speed 20%
- Snow/Icy Pavement
  - Increased Stopping Distances/Time
- Complete Stop at All Signs
- All Traffic Signals Red (Complete Stop)
- Global Turn Delays (R/L)

PROJECT PARAMETERS

"Average" Scenario A

- Drive Speed Limit
- Dry Pavement
  - Baseline Stopping Distances/Time
- Complete Stop at All Signs
- All Traffic Signals Red
- Global Turn Delays (R/L)

"Average" Scenario B

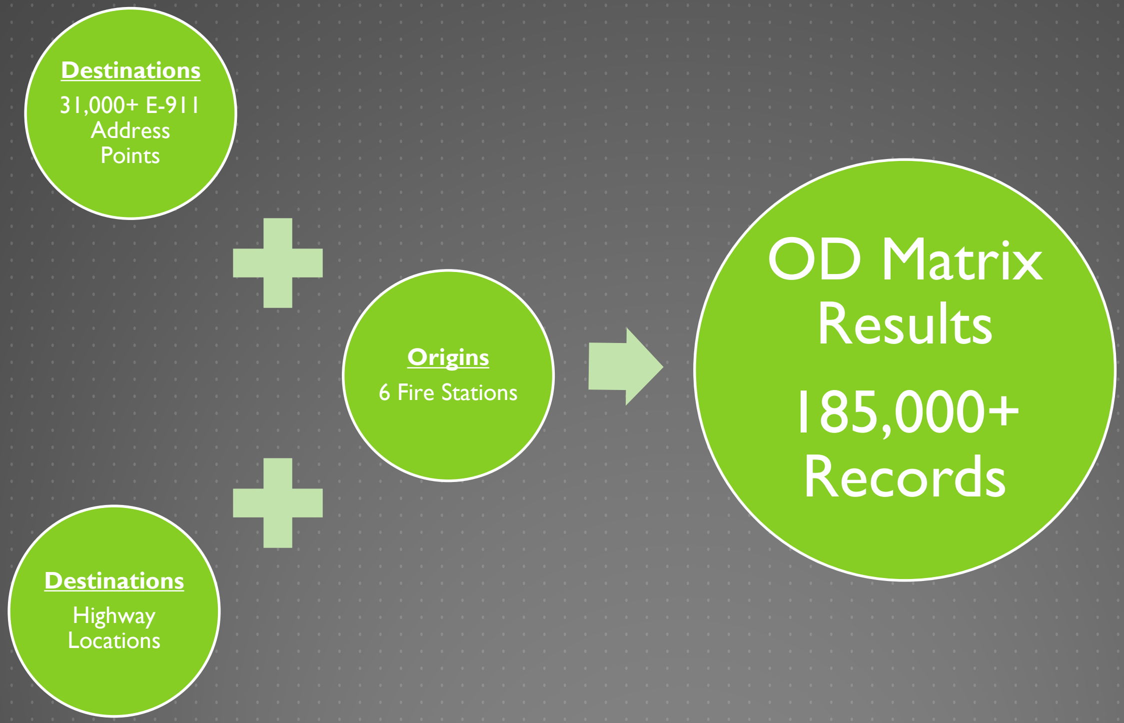
- Drive Speed Limit
- Wet Pavement
  - Increased Stopping Distances/Time
- Complete Stop at All Signs
- All Traffic Signals Red
- Global Turn Delays (R/L)

GO!… EXECUTE YOUR PLAN

- Execute the Plan for Every Environmental Condition (Best, A, B, Worst)
  - Adjust:
    - Networks Speeds
    - Turn Impedances
    - Global Turn Settings
  - Solve OD Matrix With Same Origins & Destinations
  - Repeat
- Process Data
- Analyze & Map Results

OD COST MATRIX

Finds and measures the least-cost (fastest) paths along the network from multiple origins to multiple destinations.



OD COST MATRIX RESULTS

For every destination, there are 6 records (6 stations). Quickest time is "First Due". Second fastest is "Second Due", etc…

Response Time (Minutes)

ODMatrix_Lines

OBJECTID *	Shape *	OriginID	DestinationID	Name	Total_Cost	EngineOrder	Total_SegLen
70002	Polyline	3	166085	Station 3 - 15616	5.497327	1	1.758415
129115	Polyline	5	166085	Station 5 - 15616	6.384164	2	2.240303
103239	Polyline	4	166085	Station 4 - 15616	6.81008	3	1.801745
49014	Polyline	2	166085	Station 2 - 15616	7.326534	4	2.67082
161969	Polyline	6	166085	Station 6 - 15616	8.289894	5	3.156734
20562	Polyline	1	166085	Station 1 - 15616	10.641494	6	4.42616

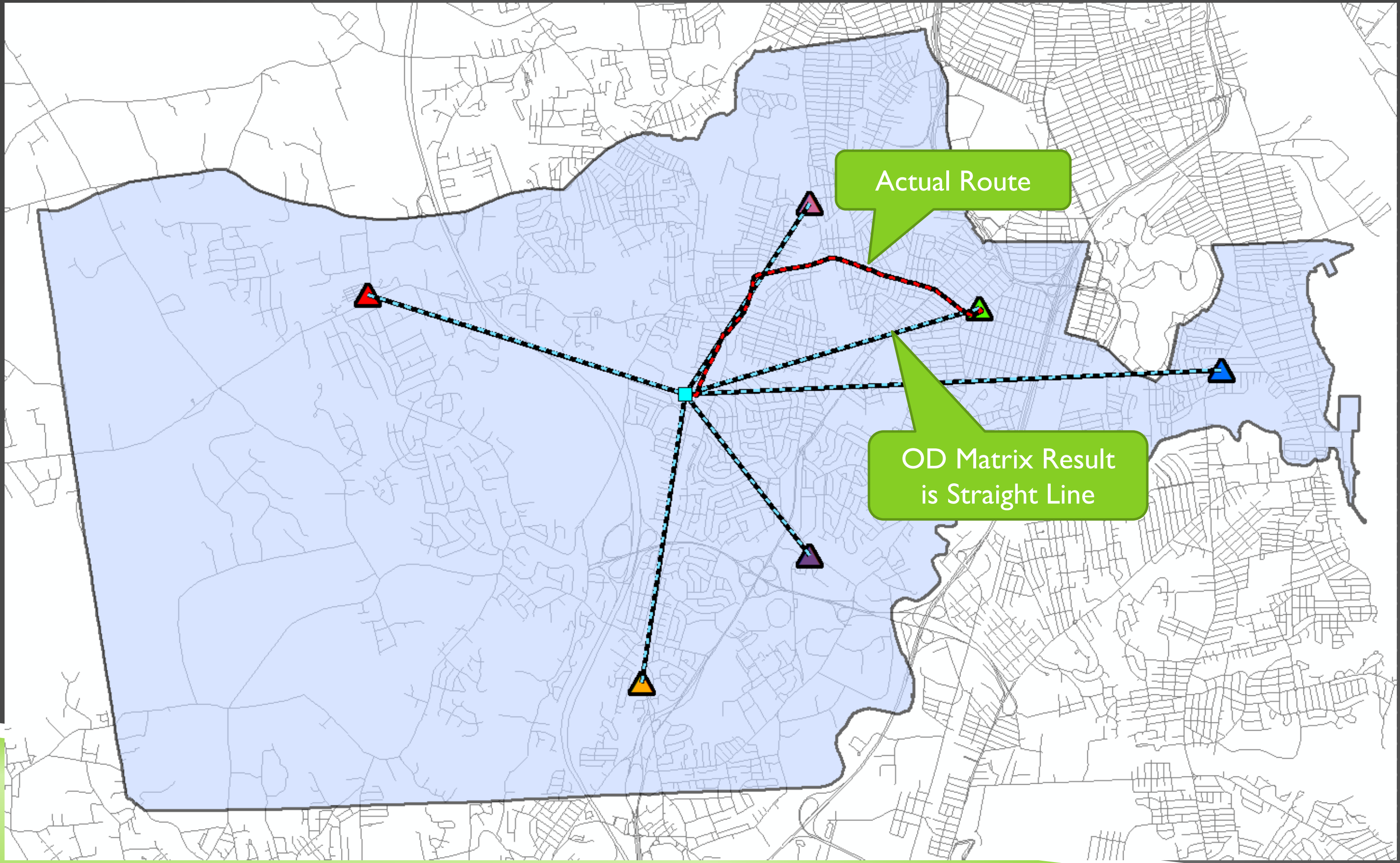
Fastest to Slowest

6 Stations for Same Destination

Distance(Miles)

OD COST MATRIX RESULTS

Each Record is displayed as a straight line from the Origin to the Destination, not as a solved route.



REARRANGING OD MATRIX RESULTS

To facilitate analysis of the results, and to make symbology more meaningful, the OD cost Matrix results are attached to the destination points.

Table - ODMatrix_Lines

ODMatrix_Lines

Name	EngineOrder	OriginID	Total_Cost	Total_SegLen	DestinationID	DestinationRank	Shape_Length	OBJECTID *	Shape *
Station 3 - 15616	1	3	5.497327	1.758415	166085	7732	8192.620434	70002	Polyline
Station 5 - 15616	2	5	6.384164	2.240303	166085	4575	10519.42621	129115	Polyline
Station 4 - 15616	3	4	6.81008	1.801745	166085	9834	7340.967133	103239	Polyline
Station 2 - 15616	4	2	7.326534	2.67082	166085	17879	11034.567156	49014	Polyline
Station 6 - 15616	5	6	8.289894	3.156734	166085	6294	11961.991284	161969	Polyline
Station 1 - 15616	6	1	10.641494	4.42616	166085	20562	19316.607081	20562	Polyline

0 (6 out of 186810 Selected)

ODMatrix_Lines

First Engine Due

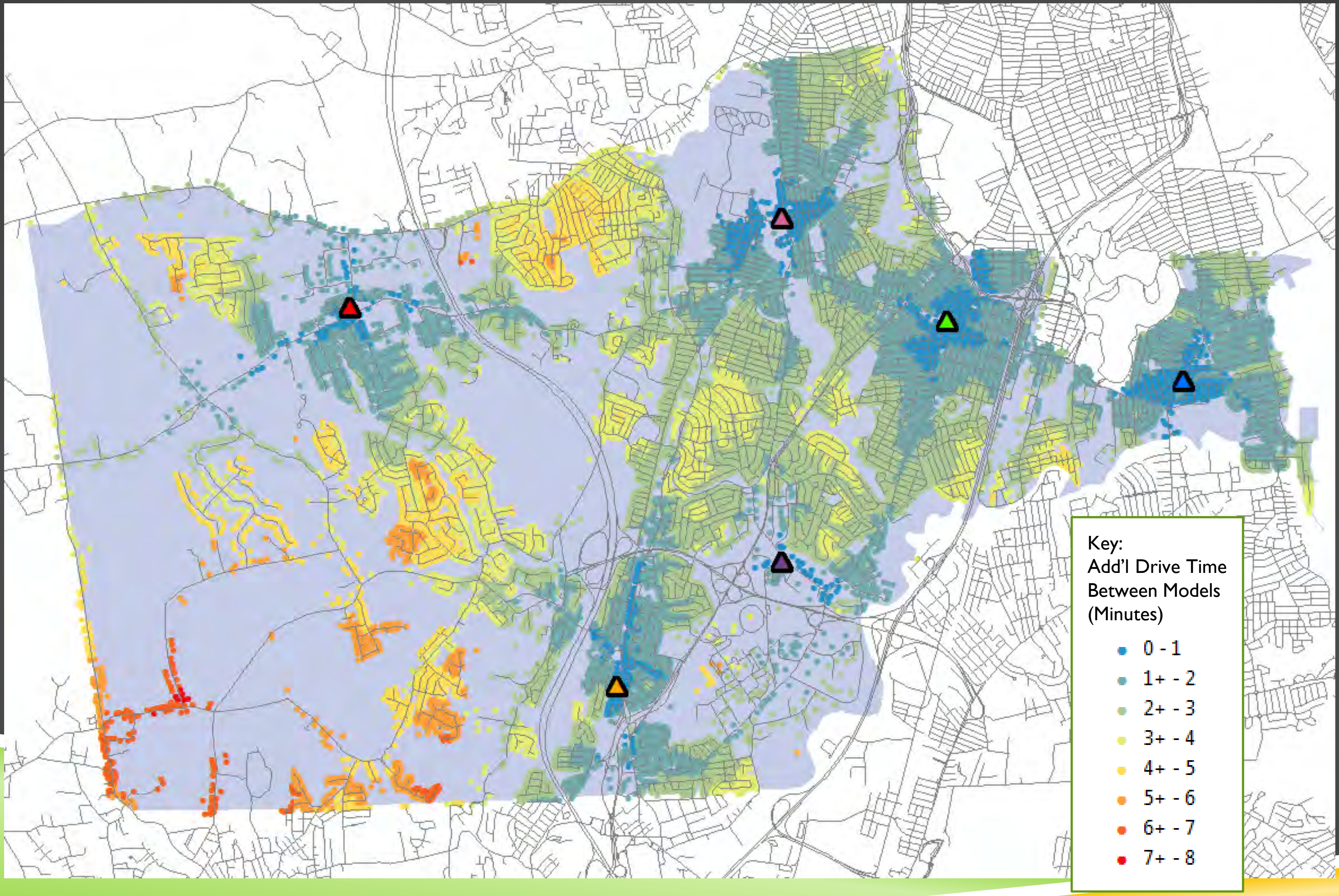
FullAddress	ProjectID	Engine1	TotCostEngine1	Engine2	TotCostEngine2	Engine3	TotCostEngine3	Engine4	TotCostEngine4	Engine5	TotCostEngine5	Engine6	TotCostEngine6
30 CARTIER ST	15616	3	5.497327	5	6.384163	4	6.81008	2	7.326533	6	8.289893	1	10.64149

1 (1 out of 31135 Selected)

First Engine Due

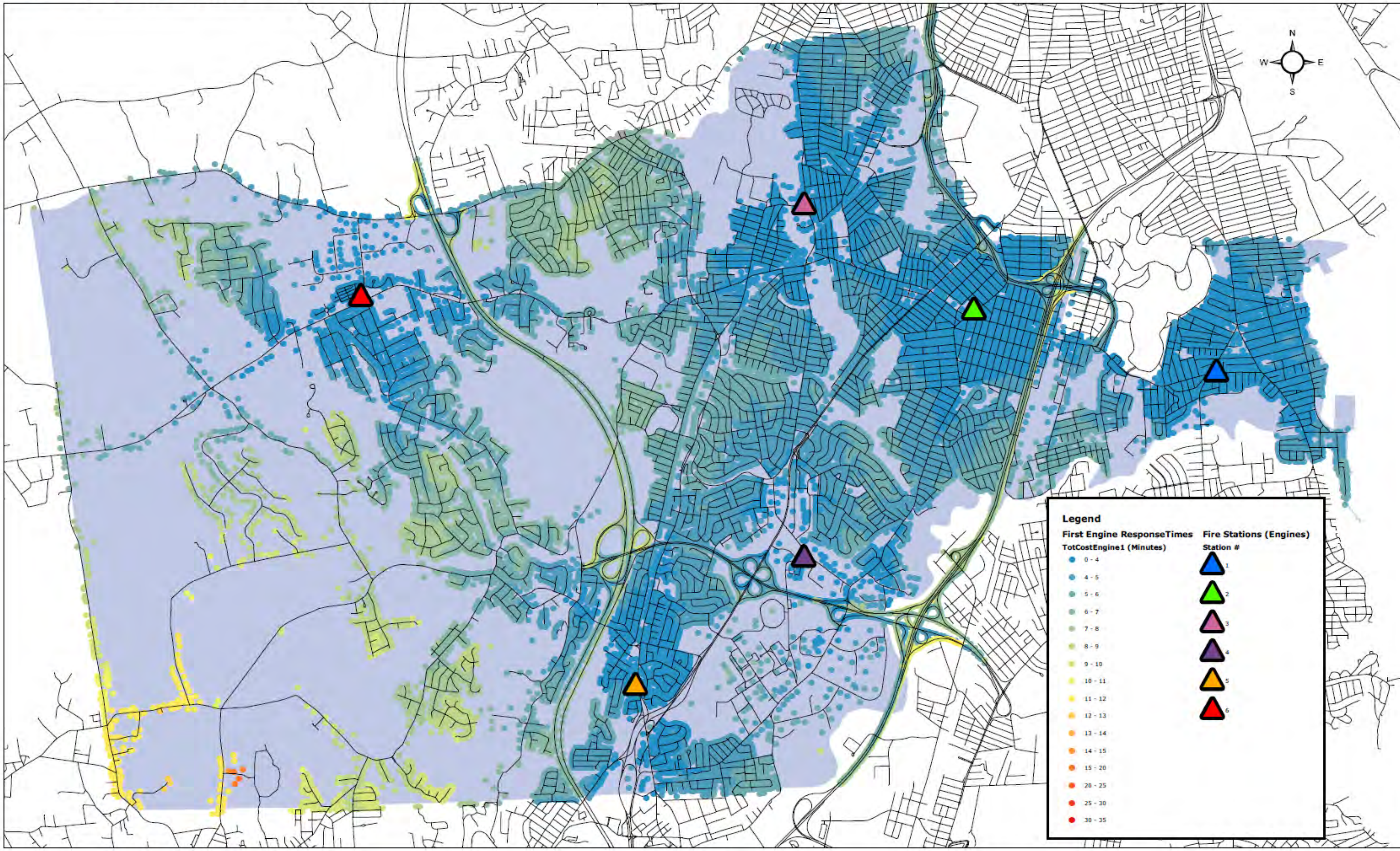
MODEL EXTREMES: BEST VS WORST CASE

Q: How do the parameters we chose affect the model response times?



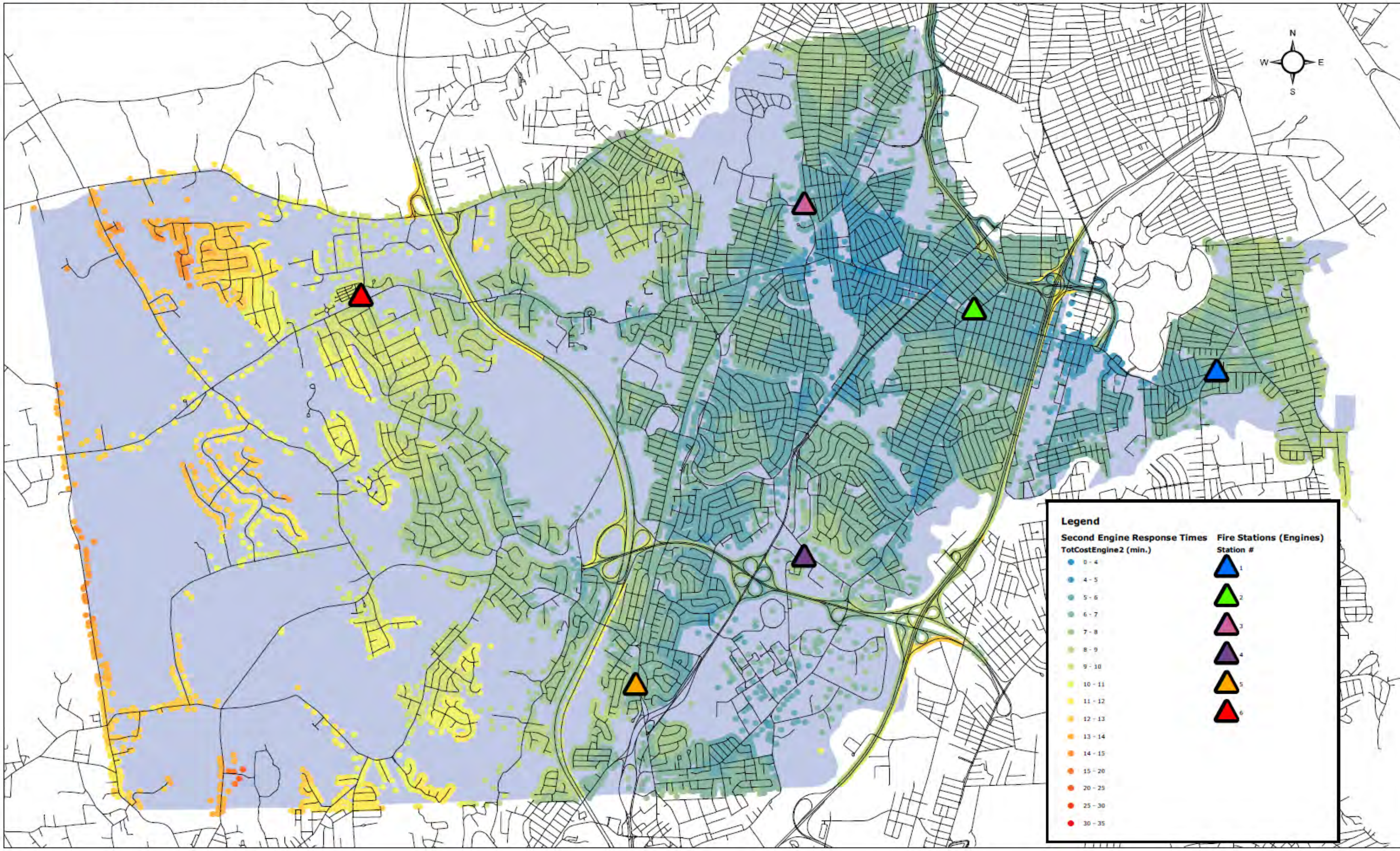
City of Cranston Fire Department
Response Times - First Engine Due

Scenario A



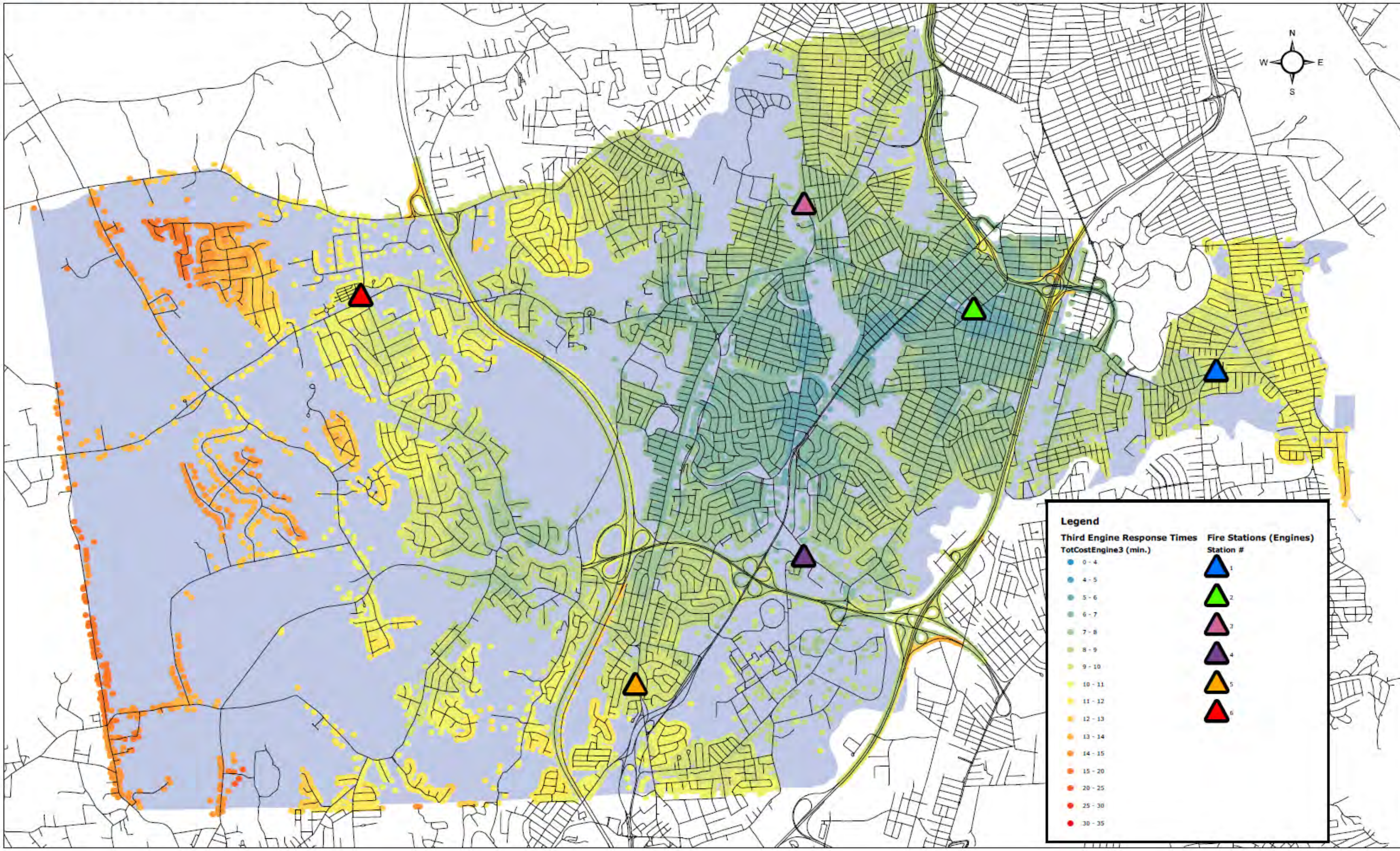
City of Cranston Fire Department
Response Times - Second Engine Due

Scenario A



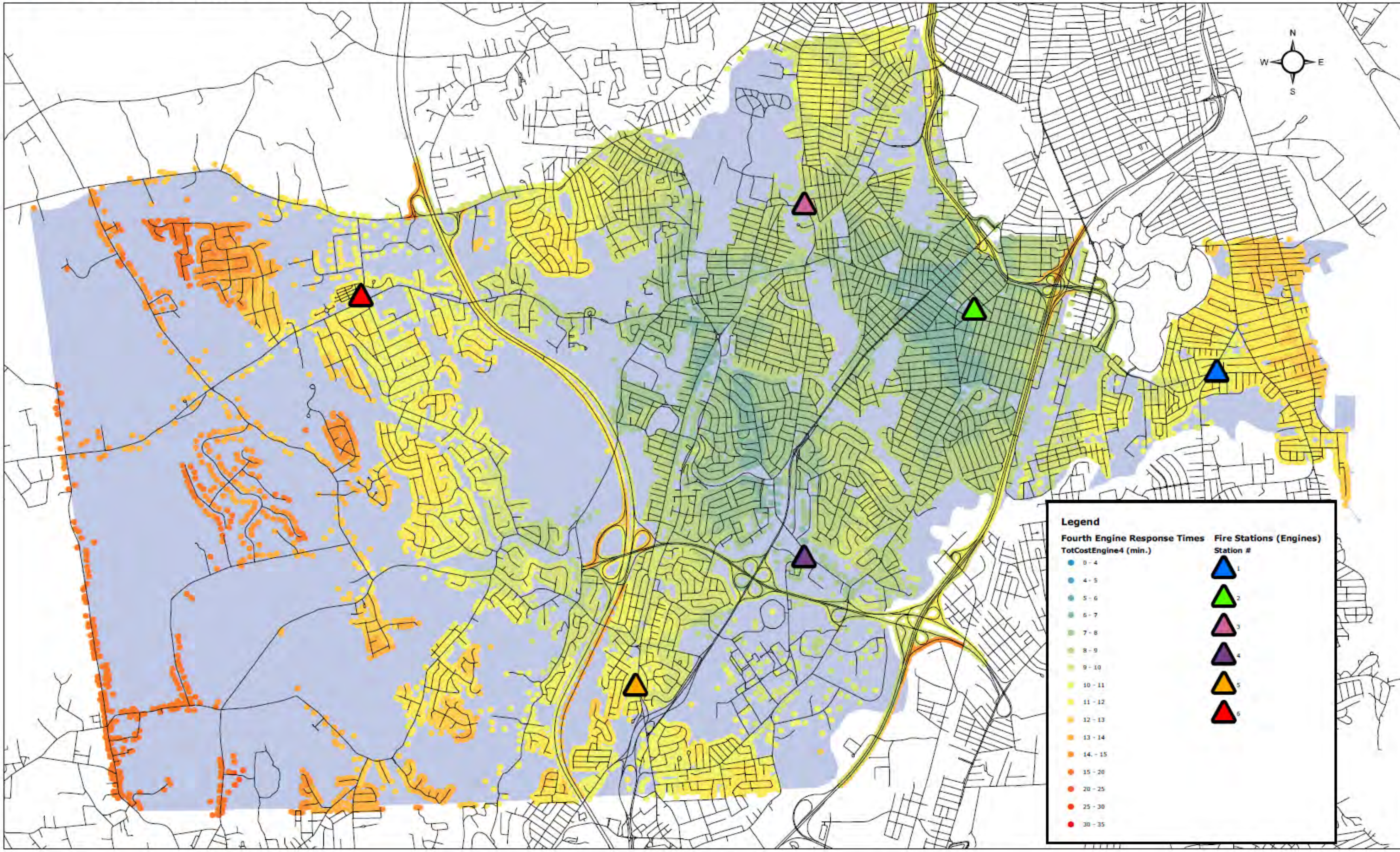
City of Cranston Fire Department
Response Times - Third Engine Due

Scenario A



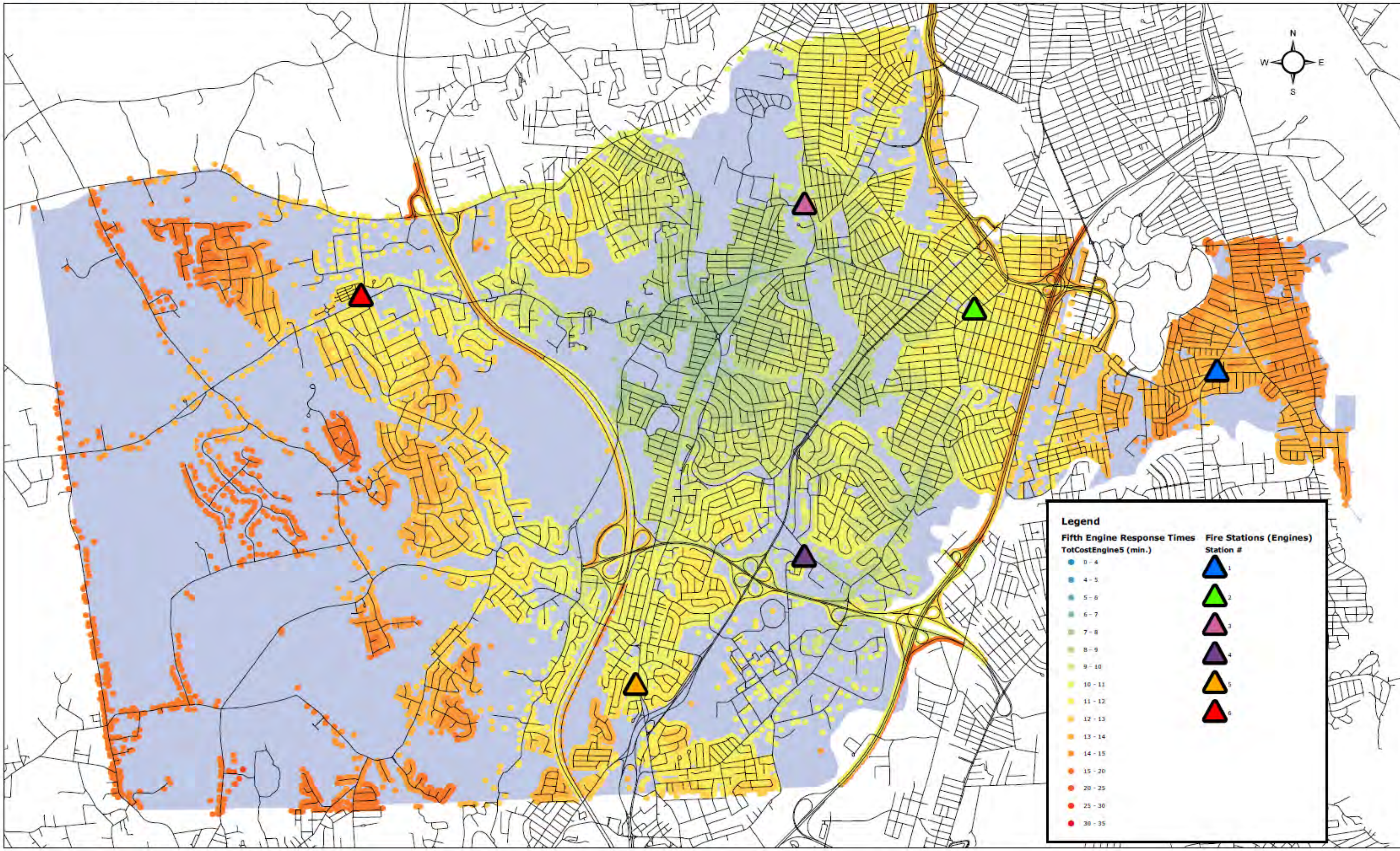
City of Cranston Fire Department
Response Times - Fourth Engine Due

Scenario A



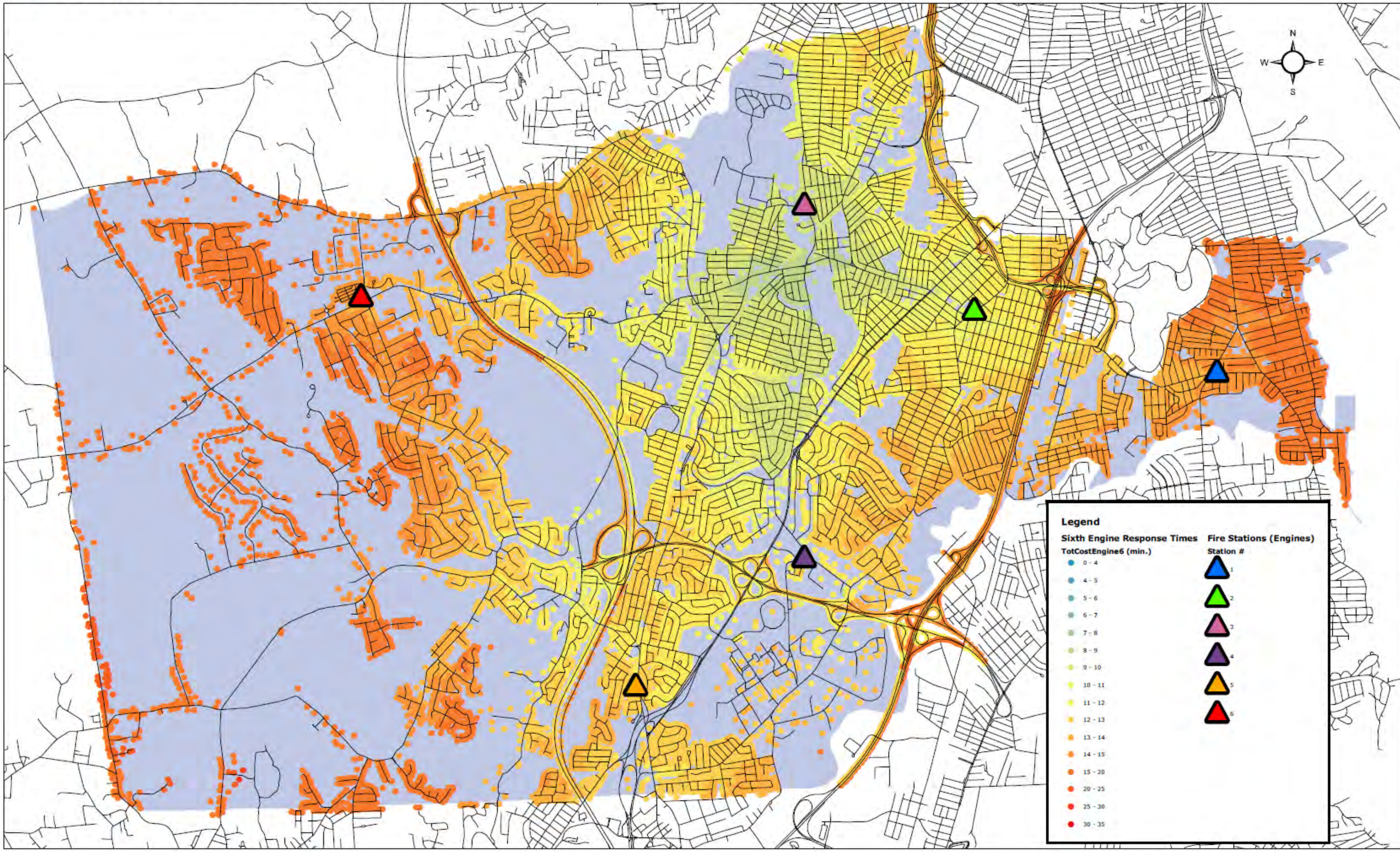
City of Cranston Fire Department
Response Times - Fifth Engine Due

Scenario A



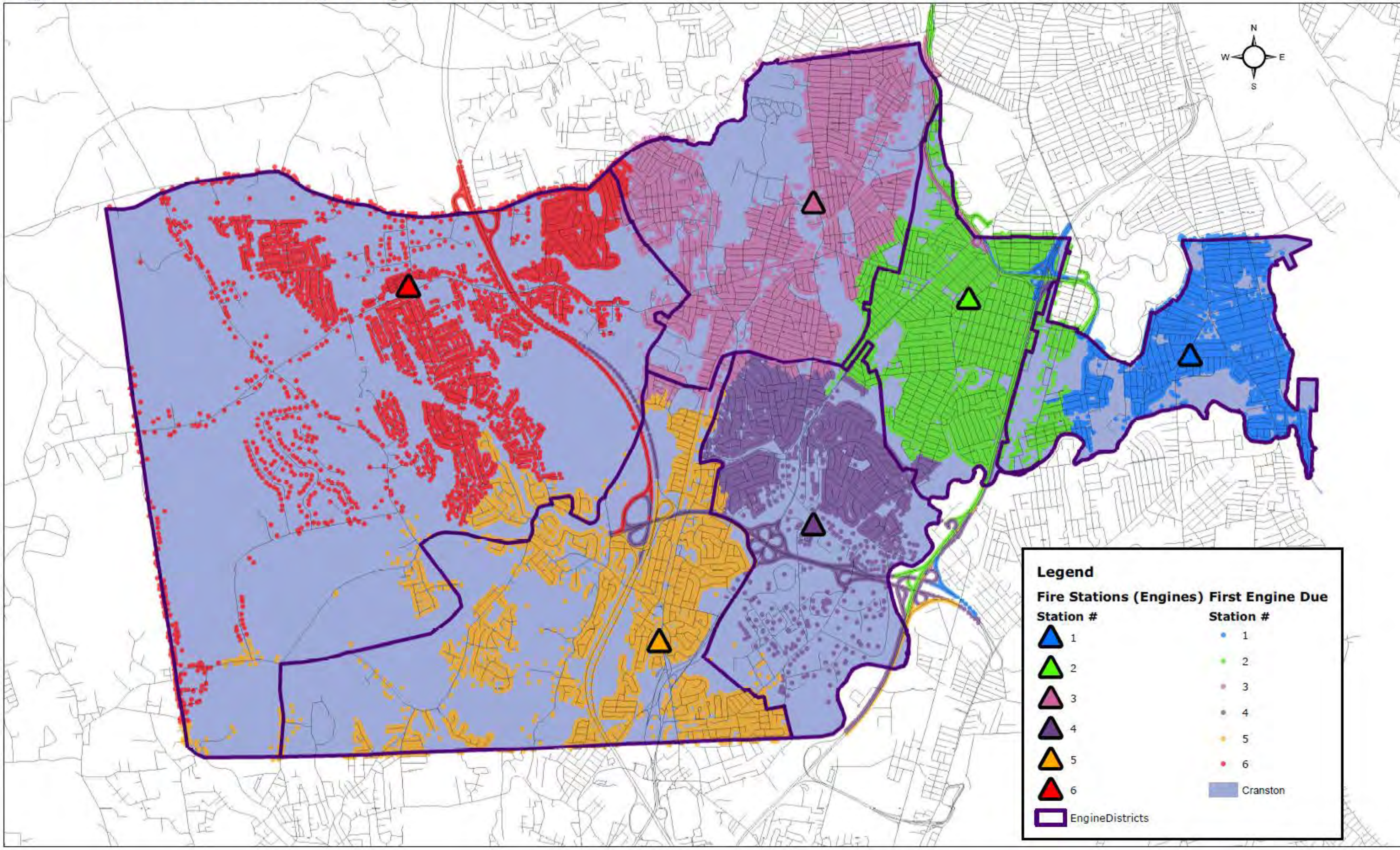
City of Cranston Fire Department
Response Times - Sixth Engine Due

Scenario A



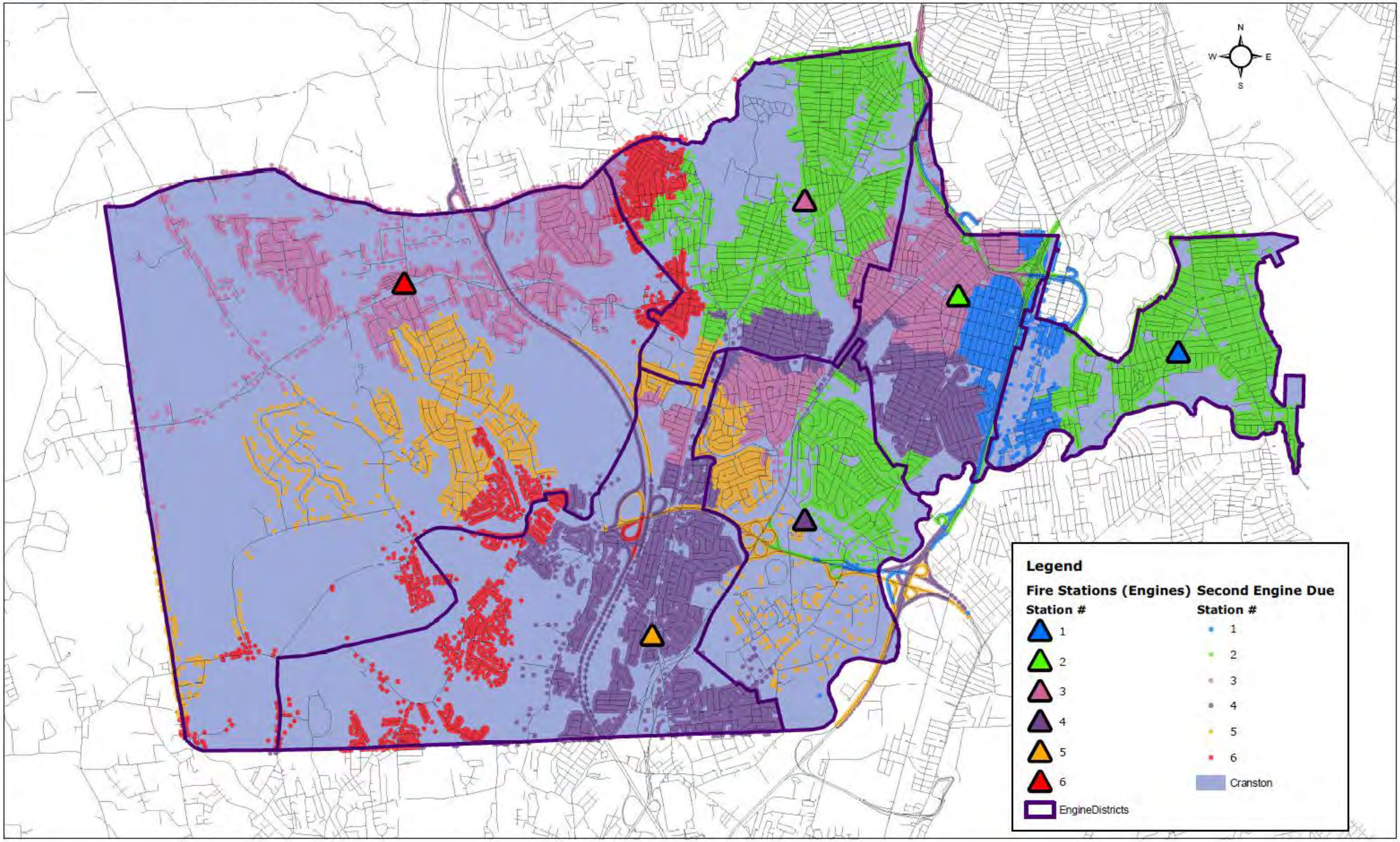
City of Cranston Fire Department
Run Order Results - First Engine Due

Scenario A



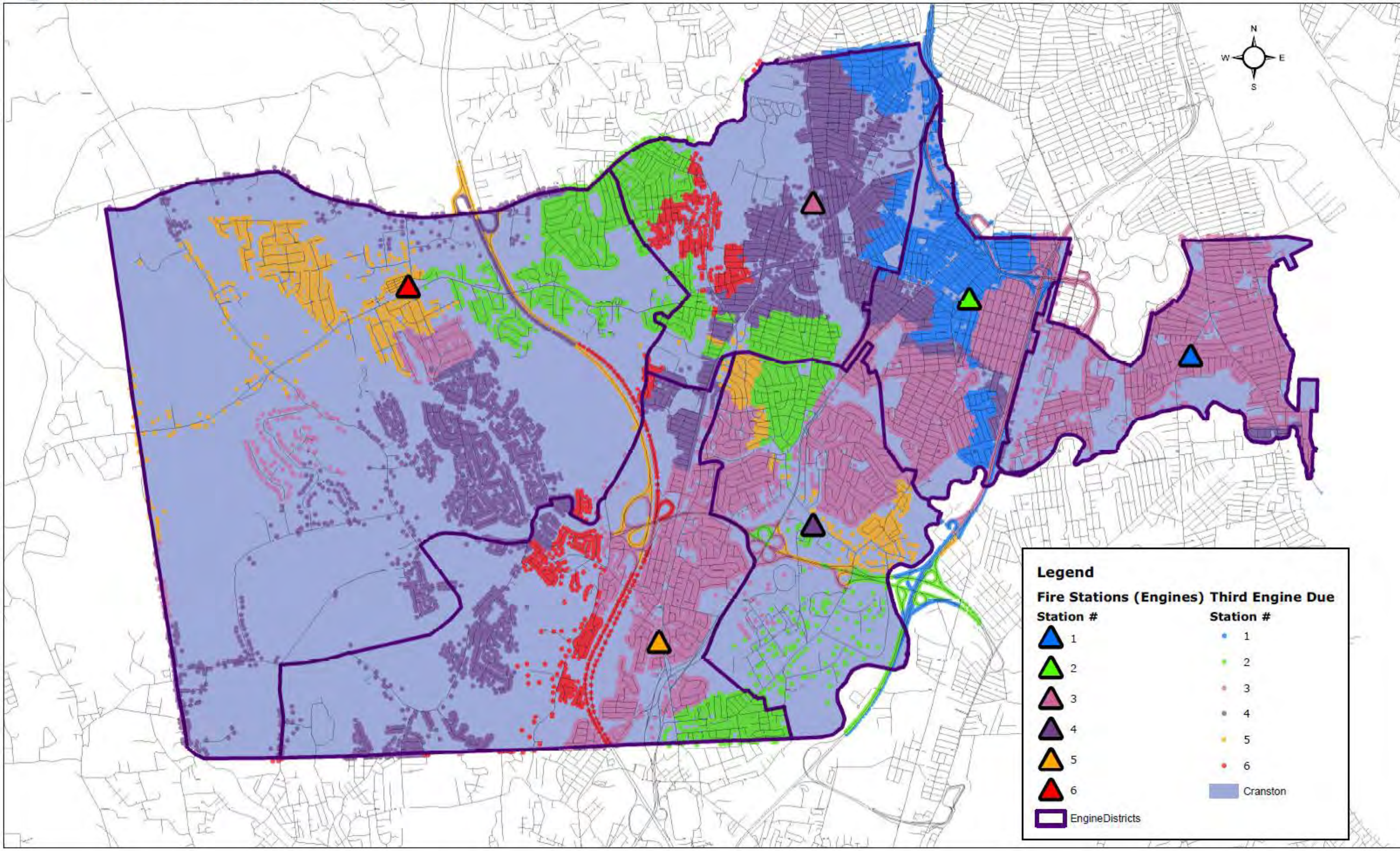
City of Cranston Fire Department
Run Order Results - Second Engine Due

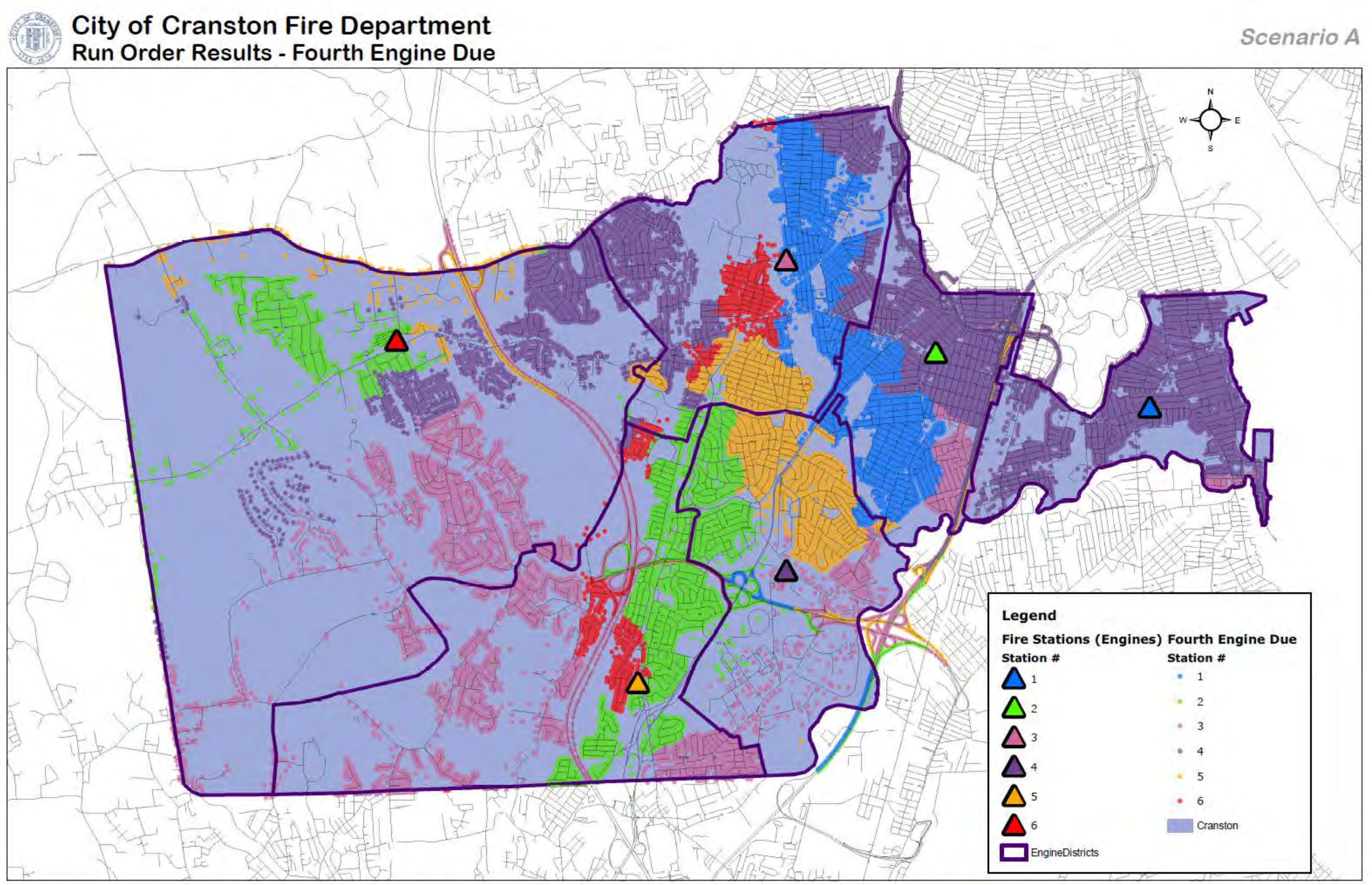
Scenario A



City of Cranston Fire Department
Run Order Results - Third Engine Due

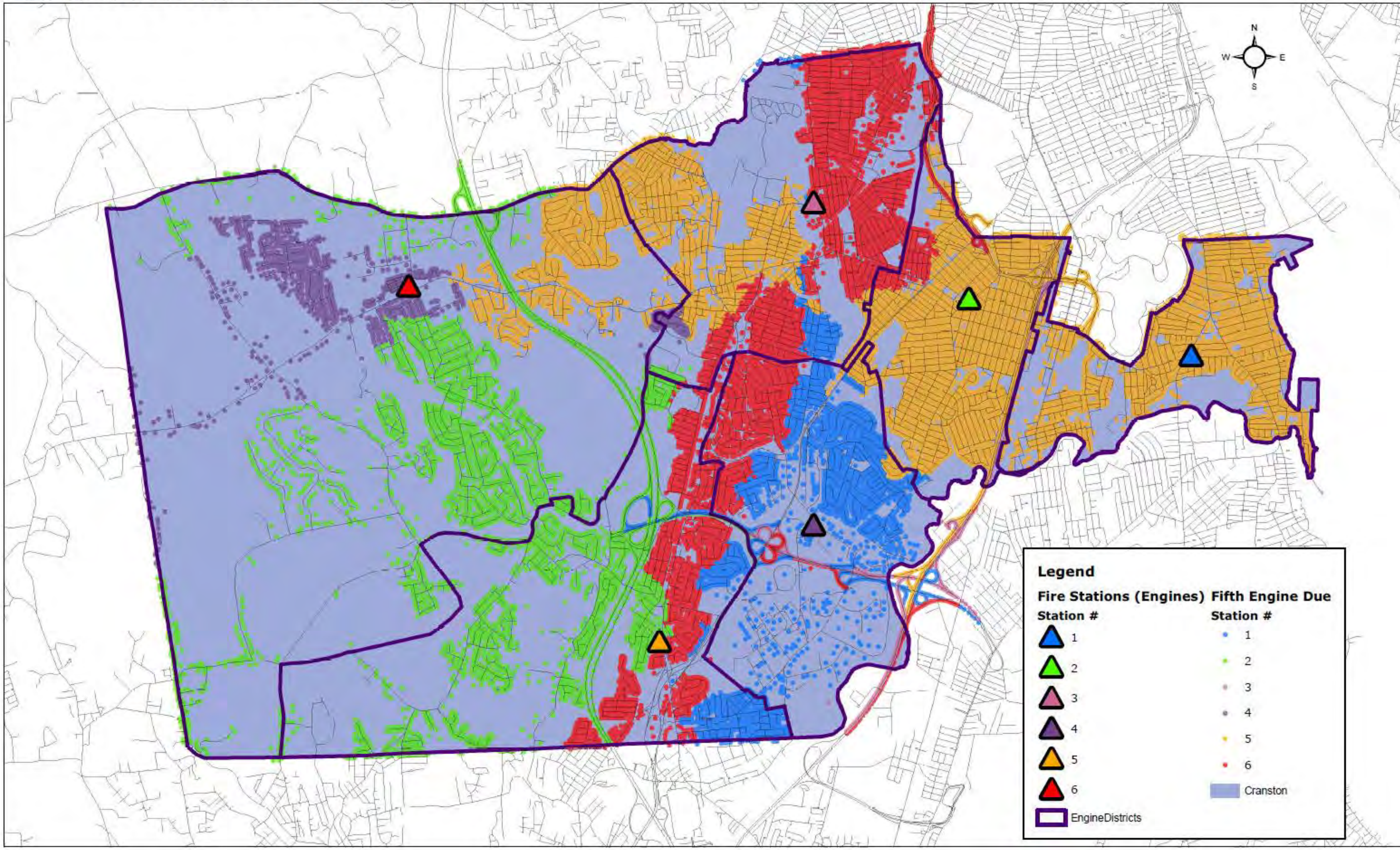
Scenario A

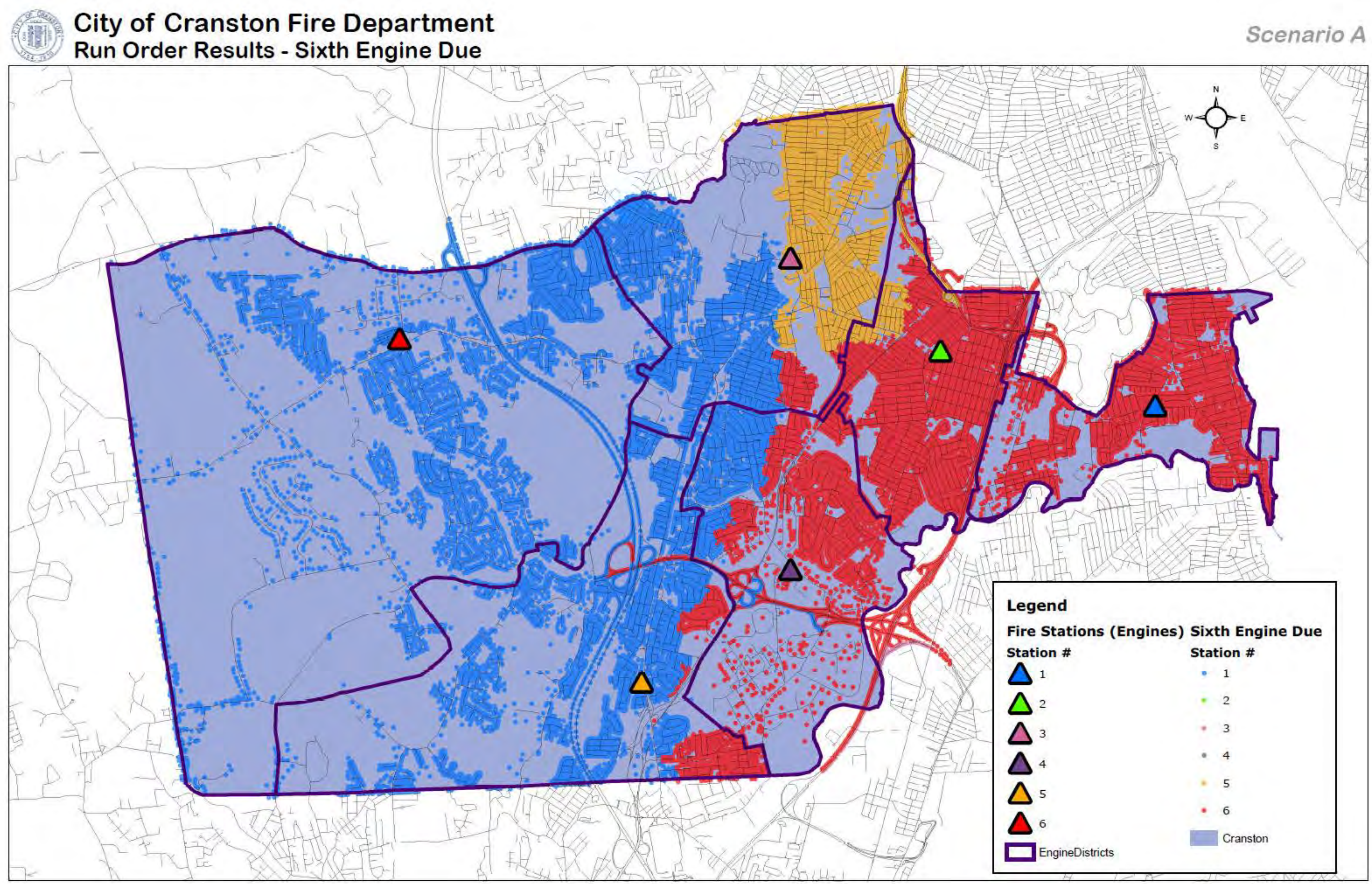



City of Cranston Fire Department
Run Order Results - Fourth Engine Due
Scenario A
N
W
E
S
Legend
Fire Stations (Engines)
Station #
1
2
3
4
5
6
EngineDistricts
Fourth Engine Due
Station #
1
2
3
4
5
6
Cranston

City of Cranston Fire Department
Run Order Results - Fifth Engine Due

Scenario A

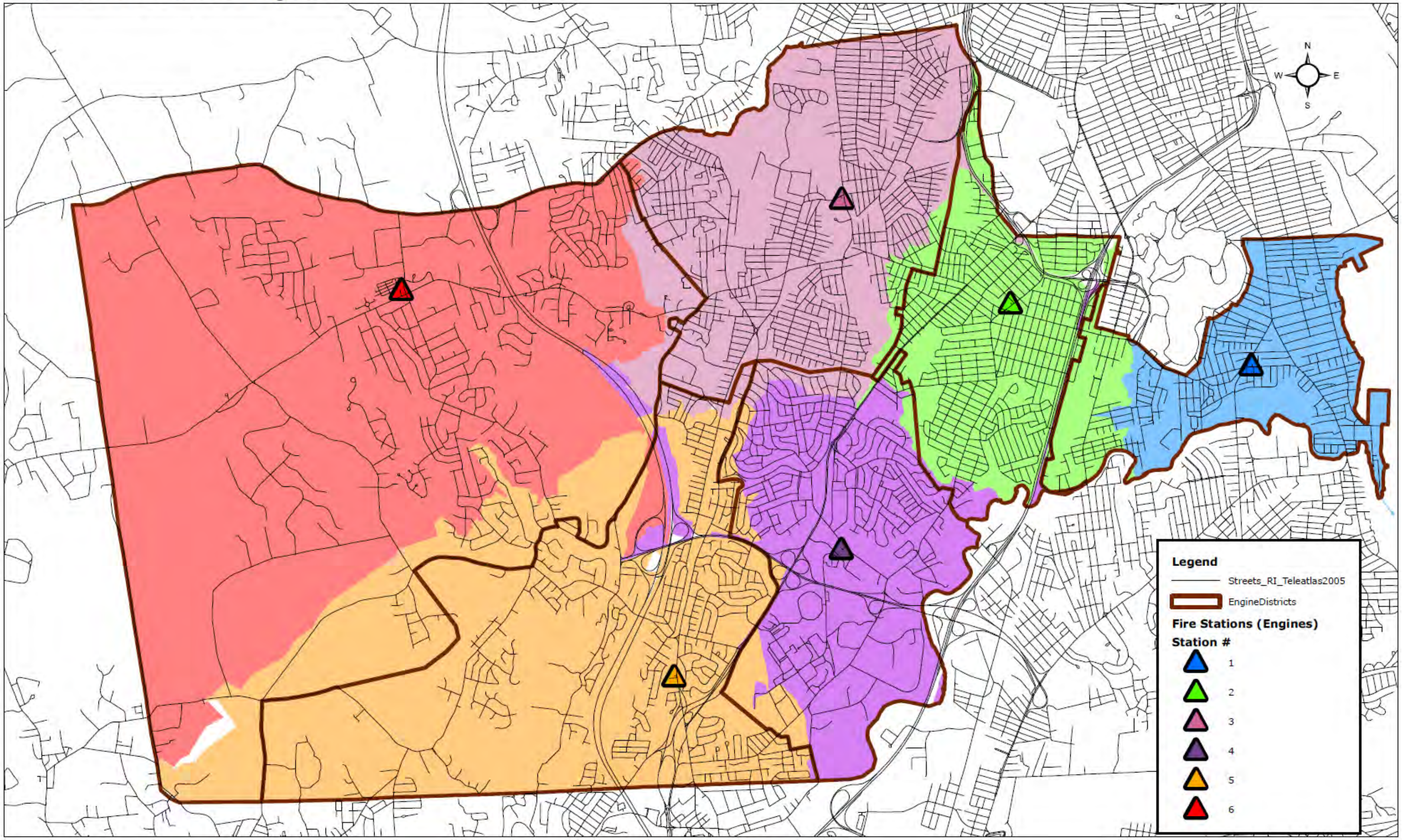




City of Cranston Fire Department
Run Order Results - Sixth Engine Due
Scenario A
N
W
E
S
Legend
Fire Stations (Engines)
Station #
1
2
3
4
5
6
EngineDistricts
Sixth Engine Due
Station #
1
2
3
4
5
6
Cranston

City of Cranston Fire Department
Service Area - Engines

Scenario A



MISSION ACCOMPLISHED!

- Determine Run Orders & Response Time for Range of Conditions
- Understand & Analyze Impact of Project Settings
- Perform What-If? Scenarios by Adjusting Data and Parameters and Solving OD Cost Matrix

- Know your Data, Project Parameters, Limitations
- There may be other considerations that have not been modeled

QUESTIONS? / COMMENTS

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